THE EFFECTS OF JUMP STYLE AND ROPE WEIGHT ON SKIPPING SPEED

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ABSTRACT

Athletes modify the intensities of jump rope workouts by using weighted ropes and performing different jump styles, or tricks. To evaluate the effect of the rope's weight and jump style performed on the maximum skipping speed, speed was measured under various test conditions. 3 common jump styles—regular jump, alternating foot, and boxer skip—were tested using 0.25 lb, 0.5 lb, 1 lb, and 2 lb ropes. It was found that jump and alternating foot are the fastest styles while boxer skip is the slowest across all weights. At 0.25 lb, the mean speed of boxer skip is slower than those of regular jump and alternating foot by 2.4 and 1.8 skips/10s, respectively. With linear increases in rope weight, the speeds of all styles decrease quadratically.

Keywords: Weighted jump rope, skipping speed, speed jump roping, jumping style

INTRODUCTION

Jump roping is an effective cardiovascular exercise that engages multiple muscles in the body. The exercise is valuable in developing upper-to-lower body coordination, improving both aerobic and anaerobic capacities, and enhancing muscular endurance for static and dynamic movements. [1] There are three main factors that determine the intensity of a jump rope session: jump rope speed, the tricks performed, and the weight of the rope. These three factors are typically utilized by trainers and jumpers to alter the workout's intensity. Speed refers to the number of rope revolutions within a period. A trick refers to the style of jump roping performed and can be varied based on how one jumps and how one swings the rope. Common tricks include regular jump, boxer jump, alternate foot jump, and fast skip. Jump ropes can be weighted either in the rope or the handles. This experiment will deal with ropes themselves being weighted.

The jump style and rope weight affect the highest skipping speed one can achieve. In this experiment, the jump rope sessions each with one of the aforementioned styles will be performed in a uniform time period with ropes of weights 0.25 lb, 0.5 lb, 1 lb, and 2lb. The skipping speed will be recorded in each session. The data will be analyzed to understand the behavior of the behavior of skipping speed for different styles at different weights.

The current literature regarding jump roping only study the effect of jump roping on various other athletic performances; there is currently very little literature on the effect of skipping speed by factors independent of one's technique. It is expected for heavier ropes to result in slower maximum speeds and for a certain style to be faster or slower than another. The data from this experiment will give jumpers and trainers an understanding of which styles are faster than others and how much speed changes due to rope weight, particularly to the end of avoiding over-exertion, pre-mature disappointment, or, alternatively, encouragement to reach higher records.

BACKGROUND

JUMPING STYLES

Regular jump, alternating foot, and boxer skip all vary with each other in landing form and foot movement. This does not affect how high a jumper raises their foot. Figure 1 shows the appropriate form and landing areas on the feet for each jump style.

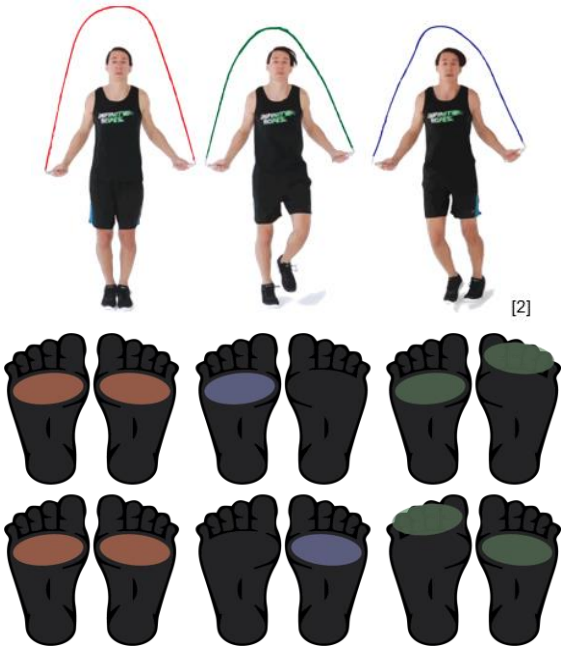

Figure 1: From left to right, regular jump, alternating foot, and boxer skip's (a) form and footwork; (b) landing areas on feet (marked by the colored sections) alternating from top to bottom positions with each skip.

Regular jump involves jumping on both feet together and landing on the balls of each foot every skip. Alternating jump is akin to running in place where each skip lands on the ball of one foot with the other in suspension. Boxer skip involves landing on the ball of one foot and the toes of the other, and, with each skip, the feet landing on the ball and landing on the toes are alternated.

JUMP ROPING MECHANICS

Jump roping is a compound movement combining the angular momentum of the rope with the vertical displacement of the body. The activity requires a synchronous cooperation of the swinging rope and the legs jumping. Successful execution of rope jumping involves the following conditions: sufficient impetus to overcome the ropes' initial inertia, sufficient momentum to maintain the rope's arc-shaped movement, and control of the centripetal force and centrifugal tendency of the rope to pull away from the arc. [1] The first two conditions are heavily affected by the mass (correlated with weight) of the ropes, while the last condition can be satisfied by several methods reliant on the jumper's skill and the properties and positioning of the rope, one of which include reducing the velocity and/or mass of the rope. Figure 2 gives a simple overview of the forces and torques involved in jump roping, neglecting friction and air resistance.

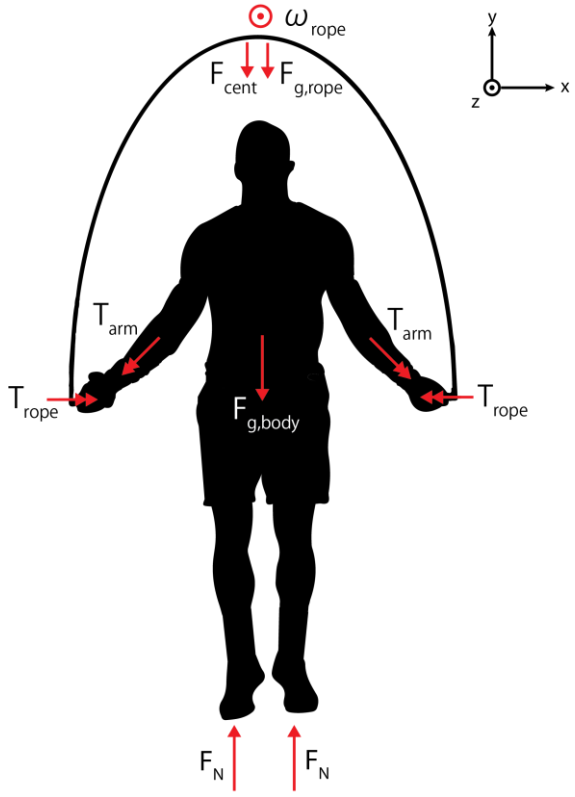

Figure 2: The jumper experiences the force of gravity pulling them down, the normal forces from jumping and landing, and the torque exerted by the swinging rope. The rope experiences gravity due to the rope's weight, centripetal force pointing inwards, and the torque exerted by the jumper's arms to maintain its angular movement.

The jumper experiences gravity, $F_{g,body}$, bringing them down with each jump, normal forces, F_N, acting on the soles of their feet when jumping and landing, and the torque, T_{rope}, exerted by the swinging rope on their wrist. The rope moving with an angular velocity, ω_{rope}, experiences centripetal force, F_{cent}, pointing towards the jumper always and gravity due to its own weight, $F_{g,rope}$, pulling it down.

To achieve maximum speed, one must assume proper jump roping form and sustain properly timed swinging and jumping. Extraneous bodily movements, which waste energy and hinder productive movements, should be minimized. These include jumping too high and excessive swinging of the arms. The arms—wrist, elbows, and shoulders, in order of descending influence [1]—maintain the rope's arc by counteracting the torque of the

rope spinning about the handles. When the mass of the rope increases, the torque consequently increases as shown the following equation: [3]

$$T = mr^2\alpha \quad (1)$$

where T is torque exerted by the rope onto the handles, m is the mass of the rope, r is the radius of the loop formed by the rope in the air, and α is the angular acceleration of the rope. A larger torque is more difficult to counteract by the arms. This results in the tendency to flails one's arms. Thus, it can be expected that an increase in the weight of the jump rope will increase the difficulty of maintaining maximum speed. Because timing one's jump to the swing of the rope is key to reaching a consistent high speed, it is important to consider that different style of jumping, due their innate different kinematics, yield different speeds. The power outputted when jumping can be evaluated with the stiffness of the legs, demonstrated as a spring-mass model. [4] Storing elastic energy, which is transferred as work, is a function of several variables, of which include knee and ankle flexion. Hence, different styles of jumping will give rise to different force and power outputs, which will affect how frequent one can repeat the motions.

PRIOR RESEARCH

A previous study led by Aristoff concluded that the force required to keep the rope in motion with its arc shape are positively correlated with rope mass, length, and angular velocity. [4] Maintaining that same force to keep maximum speed increases with difficulty as the rope gets heavier, which can attest to the differences is maximum attainable speeds with different rope weights. Another study led by Cavagna shows that there are different relations between vertical force and displacement during the rebound (effective time colliding with ground) in walking, running, and trotting. [6] This demonstrates that the magnitude of force associated with different styles is related to how quick one can successively jump, which correlates to the expected performance differences in jump styles since different styles will experience different forces due to the different contact areas of the feet to the ground. This offers an understanding as to why the different jump styles can be performed at varying speeds. However, there is currently no data regarding skipping speed.

EXPERIMENTAL DESIGN

This section discusses the setup used for measuring and recording data for the experiment. Figure 3 shows how the skipping speed was measured.

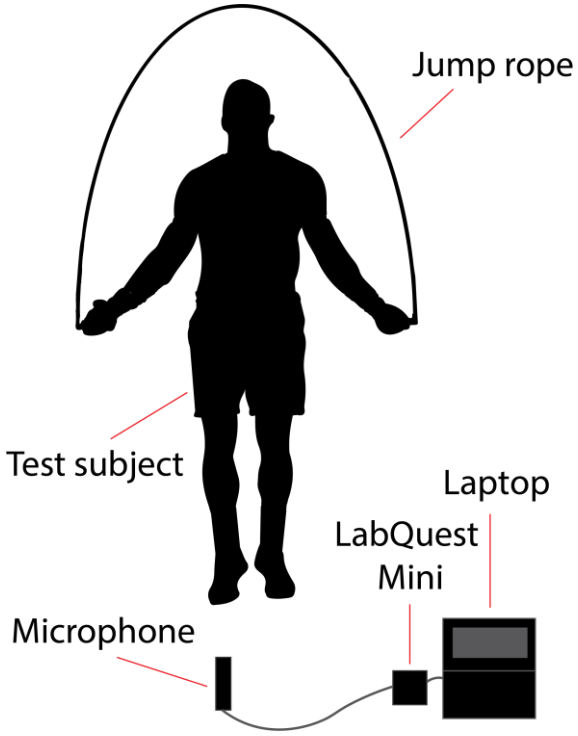

Figure 3: Experimental setup with microphone on the ground measuring the sound of the jump rope striking the ground and connected to LabQuest Mini, which is in turn connected to a laptop for data collection.

To calculate the skipping speed of each run, a Vernier Microphone (MCA), which measures sound pressure in arbitrary units, was used to measure the sound of the jump rope striking the ground with each revolution. The sound data was recorded through a Vernier LabQuest Mini at sampling rate of 10 kHz. Six runs were taken for each of the three jump styles of interest—regular jump, alternating foot, and boxer skip—with 0.25 lb, 0.5 lb, 1 lb, and 2lb Crossrope® jump ropes each. One test subject with 5+ months of jump roping experience in the three styles was used, and every run was 10 seconds in duration.

RESULTS AND DISCUSSION

Offset sound pressure during each jump rope session was measured to determine the number of revolutions within the 10-second period. As shown in Figure 4, the

peaks in sound pressure are when the rope strikes the ground after each revolution.

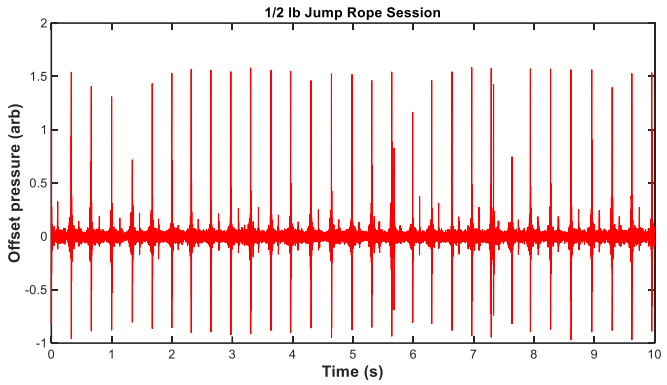

Figure 4: Offset pressure (arb) vs time (s) of a representative sample session for regular jump with a 0.5-lb rope. The peaks occur when the rope strikes the ground, indicating a revolution. The number of peaks is the number of skips in the duration.

Through peak estimation with a minimum peak height of 0.5 arb and minimum peak separation of 0.1s, the number of peaks was found. This value, the number of skips in 10s, is the speed of a session. With this method, the speed of the session in Figure 2 is 31 skips/10s. This method was repeated to find the average speed for jump sessions of all styles and weights, as shown in Figure 5 and Table 1.

Table 1: Average speeds and uncertainties with 95% confidence for regular jump, alternating foot, and boxer skip across rope weights of 0.25 lb, 0.5 lb, 1 lb, and 2 lb.

	Regular Jump (skips/10s)	Alternating Foot (skips/10s)	Boxer Skip (skips/10s)
0.25 lb	32.17 ± 1.03	31.33 ± 0.86	28.67 ± 0.54
0.5 lb	30 ± 0.94	30.67 ± 0.54	28.17 ± 0.79
1 lb	28.83 ± 0.79	29.5 ± 0.57	27.33 ± 0.86
2 lb	22.33 ± 0.86	22.5 ± 0.57	21 ± 0.66

Figure 5: Speed across different rope weights grouped by jump style. For each style, weight goes from 0.25 lb to 2 lb as color goes from light to dark.

The downward trends in Figure 5 show that, independent of style, skipping speed decreases as rope weight increases. Universally, the decrease in speed is sharpest from 1-lb to 2-lb ropes. The highest recorded speeds were 32.17 ± 1.03 skips/10s and 31.33 ± 0.86 from 0.25-lb regular jump and alternating foot, respectively. Boxer skip was the slowest style at each weight and recorded the slowest speed 21 ± 0.66 skips/10s among all sessions.

ANOVA and Hypothesized Mean Difference (HMD) tests were conducted to quantify the differences in speed across styles and weights. Firstly, ANOVA tests were conducted to determine if there was variance in average speeds within jump styles at each rope weight as well as within rope weights within for each jump style. The resulting p-values for the different styles at each weight were smaller than 0.05 for all rope weights, thus at each weight, there is statistically significant variance with 95% confidence within the three jump styles. In addition, the resulting p-values for each jump style across different weights were also all smaller than 0.05, thus there is also statistically significant variance with 95% confidence within speeds at different rope weights for each jump style.

With the confirmation of statistically significant variance, HMD tests at a 95% confidence level were carried out on the same sets of samples to quantify the differences between the average speeds. At all weights, the result of the HMD test between regular jump and alternating foot was negative, indicating there is no statistically significant difference between the average speeds of those two styles with 95% confidence. At 0.25 lb, the average speed of regular jump was 2.4 skips/10s faster than the average speed of boxer skip. At 0.5 lb, 1

lb, and 2 lb, the average speed of regular jump was higher than that of boxer skip by 0.8 skips/10s, 0.5 skips/10s, and 0.4 skips/10s, respectively. From 0.25 lb to 2 lb, the average speed of alternating foot was higher than that of boxer skip by 1.8 skips/10s, 1.6 skips/10s, 1.2 skips/10s, and 0.7 skips/10s, respectively. Asides from the 0.25-lb rope, alternating foot was faster than boxer skip by a higher margin that regular jump was. Additionally, as the weight increases, the gap between speeds decreases, such that the variance is negatively correlated with weight.

The same test was carried out to compare the changes in speed of each style across the different rope weights. For regular jump, the average speed at 0.25 lb was higher than that of 0.5 lb by 0.9 skips/10s, that of 0.5 lb was greater than that of 1 lb by 0.09 skips/10s, and that of 1 lb was greater than that of 2 lb by 5.5 skips/10s. For alternating foot, the result between 0.25 lb and 0.5 lb was negative, the average speed of 0.5 lb was greater than that of 1 lb by 0.5 skips/10s, and that of 1 lb was greater than that of 2 lb by 6.3 skips/10s. Lastly, for boxer skip, the result between 0.25 lb and 1/2lb and between 0.5 lb and 1 lb were both negative, and the average speed at 1 lb was greater than that at 2 lb by 6.3 skips/10s. Asides from regular bounce, there was no statistically significant decrease in average speed from 0.25 lb to 0.5 lb. From 0.5 lb to 1 lb, there was a very minor to no statistically significant difference between those two weights. Thus, the largest change in speed occurred between 1 lb and 2 lb, which was the largest difference in weight. Regular jump had the largest difference in average speeds between 0.25 lb and 2 lb with 8.7 skips/10s. That of alternating foot was 7.9 skips/10s, and of boxer skip, which had the lowest change in speed from 0.25 lb to 2 lb, was 6.9 skips/10s.

To visualize and further understand the behavior of the skipping speed across weights for each style, a 2nd-degree polynomial was fitted to the data as shown in Figure 6.

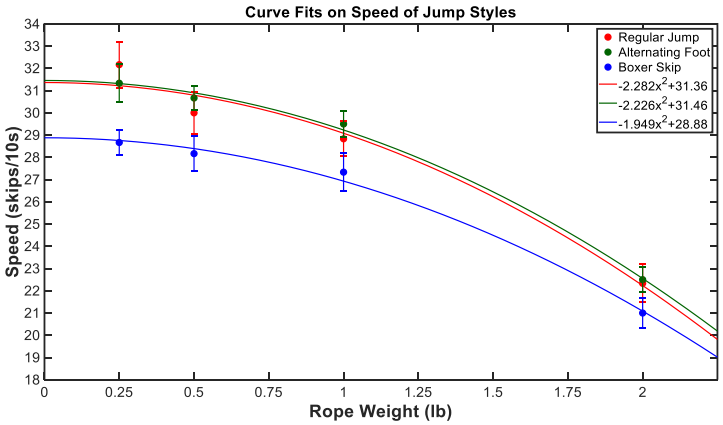

Figure 6: 2nd-degree polynomial functions fitted to all three jump styles. There is a quadratic decrease in speed as weight increases for all styles. Boxer skip is modeled as the slowest while alternating foot is modeled narrowly faster than regular jump.

Displayed in Figure 6, boxer skip is much slower than regular jump and alternating foot, while alternating foot is only marginally faster than regular bounce. The recorded speeds of those two styles did not have a statistically significant difference, but means of the data samples for alternating foot were narrowly larger at all weights save for 0.25 lb. The coefficients of the x^2 term are, in skips/10s-lb^2, -2.282 ± 0.283, -2.226 ± 0.166, and 1.949 ± 0.118 for regular jump, alternating foot, and boxer skip, respectively. There is no statistically significant difference between the coefficients' magnitude for regular jump and alternating foot, but that of boxer skip is statistically significantly smaller than the other two. This lower magnitude reflects the style's slower change in speed across rope weights. The intercepts are, in skips/10s, 31.36 ± 0.585, 31.46 ± 0.345, and 28.88 ± 0.39 for regular jump, alternating foot, and boxer skip, respectively. These reflect the speed one can attain using extremely lightweight ropes, termed speed ropes, which can weigh as low 0.0625 lb. [7]

While these results were reasonable, there were potential rooms for error in collecting data. When jump roping at maximum speed, a natural tendency is to swing the rope such that it does not strike the ground very loudly. Thus, the test subject deliberately ensured all revolutions struck the ground, so that none of the skips would not be missed by the microphone. One surprising result was not seeing a statistically significant difference in speed between alternating foot and regular jump. Because alternating foot is the jump style used by professional jump ropers in speed competitions, it was expected that alternating foot would have been

distinguishably faster than regular jump. A potential source of error relating to this is that each style was measured from rest at the beginning of the 10 seconds. While maximum effort was used for each run, alternating foot naturally takes longer to reach its maximum speed, similarly to how sprinters do not reach maximum speed from rest. It is easier to reach maximum speed jumping up and down. Another limitation of this experiment is the duration of the jump rope sessions. Typically, when focused on speed, a jumper would jump for longer durations, such as a minute, or with a target number of skips. Future work to build on this study can include conducting sessions of longer lengths to capture the behavior of speed with time and to use more test subjects as jumper to observe the reliability of this trend.

CONCLUSIONS

Speed is a typical indicator of the intensity and dexterity in which one jump ropes and is thus an important measurement for athletes. Different jump styles yield different maximum attainable speeds for a jumper, and changing the rope weight to alter the intensity at which muscles are worked will also affect the maximum speed.

At all rope weights, regular jump and alternating foot are the fastest jump rope style among the three styles, while boxer skip is significantly slower. As the rope weight increases, the speeds of all styles decrease, but they also draw closer together. Thus, at 2 lb, the speeds of the three styles are less distinguishable from each other than at 0.25 lb, where the differences in speeds are more pronounced. From 0.25 lb to 2 lb, regular jump decreases in speed the most while that of boxer skip decreases the least, thus regular jump varies the most depending on rope weight. One can expect greater changes in speed with different rope weights in regular jump and the least changes in boxer skip. However, stepwise changes in weight, except for the 1lb to 2 lb change, (i.e. 0.25 lb to 0.5 lb and 0.5 lb to 1 lb) do not yield changes in speed greater than 1 skip/10s for all styles. If a jumper, for example, were to increase the rope weight from 0.25 lb to 0.5 lb to further work their muscles, they should expect to experience a maximum speed very similar to what they experienced at 0.25 lb.

With this information, trainers and jumpers alike can understand that employing regular jump or alternating foot with a 0.25 lb or less rope will yield the fastest skipping results. And, it is hoped they can set better expectations and goals when they alter rope weights.

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